



REPORT

ON THE

PURIFICATION OF DRINKING WATER BY ALUM.

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THE many discoveries that have been made during the last years in regard to the transmission of diseases by drinking-waters have caused attention to be directed to the methods of its examination and the processes for purifying it. Chemical analysis can establish the presence of albuminoid matter in water, and by its means we are able to state if the water under examination can become a suitable nidus, or medium, for the development of disease germs. If the germs are actually there, or if the water contains a virus, or ptomaine,[†] biological examination alone can determine.

While physicians and scientific men are experimenting on the methods of water examination, and are endeavoring to understand fully the meaning of the results obtained, the public are chiefly interested to have some method by which they can purify their drinking water in a simple, cheap, efficacious, and expeditious manner.

Running over the substances which have been suggested and tried for the purification of water, there is none that seems to offer the advantages of alum. Particular attention was directed to its use by Jeunet in 1865, in an article published in the *Moniteur Scientifique* (page 1007). He found that 0.4 gramme of alum to a litre of water (23.3 grains to one gallon) rendered it drinkable, even when it was quite full of foreign matter. The time taken for this clarification was from seven to seventeen minutes.

Alum is a double sulphate of potash and aluminium, and in this case breaks into potassium sulphate, which remains in solution, and a basic aluminic sulphate. This basic sulphate of aluminium, the composition of which is undetermined, precipitates as a more or less gelatinous and flocculent mass, and carries down with it the foreign matters and humus bodies. The sulphuric acid set free in the formation of the basic aluminic sulphate, attacks the earthy and alkaline carbonates, which are always present, and forms with them sulphates, setting carbonic acid free. Aluminic sulphate acts like alum. Aluminic acetate and ferric acetate do not give such good results. Peligot, however, found that ferric chloride (sesquichloride of iron) acted well, and Scherer recommends the use of a neutral sulphate of iron.

In the last years an extensive use of alum has been made in the many processes of purifying water, sewage, etc. It is not improbable that aside from its

effect in precipitating matter mechanically by envelopment with the precipitating basic aluminic sulphate, the alum exerts a distinct coagulative action on the albuminous substances in the water, rendering them insoluble, and thus causing their precipitation; perhaps the same or similar effect that alum produces in the tawing of leather. One of the most prominent applications of alum at present is in the Hyatt filter. By the addition of a minute amount of alum, water is rendered capable of a most perfect mechanical filtration.

The fact that alum is cheap, and can be obtained in quite a pure state at any drug store, places it within the reach of every one. Its sharp taste precludes the possibility of its being swallowed by mistake. But even should it be swallowed by mistake, no great harm would be likely to ensue, unless a large amount were taken. In medical treatment as high as 30 grains are given in a single dose, and this may be repeated four times per day. If it can be proved that alum not only clarifies a water, but also removes from it disease germs and ptomaines, its use will prove of incalculable value to the human race, for facts begin to indicate that a vast number of diseases are communicated through drinking water.

The investigation of the effects of alum on drinking water falls under the several heads—

I. Clarification of the water by settling.

II. Clarification of the water by filtration.

III. Use of water clarified by alum in manufacturing.

IV. Removal of disease germs.

V. Removal of ptomaines.

VI. Removal of organic matter.

The investigation must needs be both chemical and biological. Only the first and part of the second cases have so far been examined.

I. THE EFFECT OF ALUM IN CLARIFYING WATER BY SETTLING.

It is evident that to obtain practical results in the clarification of water by alum, it must be added in such small amounts as to leave no unnecessary excess, and that neither taste nor physiological action should be imparted to the water. At the time of our experiments (January, 1885) the New Brunswick city water was quite turbid from clayey and other matters, so that we were able to obtain some very reliable results.

The amount of alum used in the experiments of Jeunet seems to be unnecessarily high, in case the water is to be drunk. Water was treated with the amount of alum recommended by

* From the advance sheets of the Annual Report of the State Geologist of New Jersey for 1884.

† Putrefaction alkaloid.

Jeunet (23·3 grains to the gallon), but no perfect settling was obtained under six hours or more; in some cases not under twelve hours. The water thus treated had no perceptible taste of alum, but it gave a decided reaction for alumina when treated with ammonia, showing that the water contained a certain amount of free alum. While the amount is evidently too small to produce any physiological effect, there seems to be no necessity to use such an excess.

To determine the effect of alum as a precipitating agent, tall cylinders were filled with water and a solution of alum was added, the whole well mixed, and allowed to stand. It was found that in varying lengths of time, depending on the amount of alum used, a gelatinous precipitate settled out, and the water above it became perfectly clear. On adding a relatively large amount of alum, and mixing, the coagulation and separation of the precipitate is at once visible, the water appearing by careful examination to be filled with gelatinous particles. The amount of alum necessary for the precipitation of a water will, of course, depend on the amounts of impurity present, but in the present case, which may be taken as a typical one, we found that 0·02 gramme of alum to a litre of water (1·2 grains to a gallon) caused the separation and settling of the impurities, so that the supernatant water could be poured off. This amount of alum was shown by numerous experiments to be about the practical limit. The complete settling took place as a rule in not less and usually more, than two days. It is evident that the amount of alum thus added is too slight to be perceptible to the taste, and can exert no physiological action. We were unable to detect the slightest taste or change in the water so treated.

Still smaller amounts of alum will produce a precipitate after longer standing. Sixty litres of the city water were treated with two grammes of alum (this was about 31 grains to 16 gallons) and allowed to stand. After forty-eight hours the precipitation seemed complete, and the water was perfectly clear, while the bottom of the vessel was covered with a brownish, slimy deposit. This substance was collected, dried, and analyzed. It gave—

Carbon.....	16·50 per cent.
Hydrogen.....	2·02 “
Nitrogen.....	0·77 “

It is evident from this analysis that a large amount of the organic matter has been removed from the water by the alum treatment.

On incineration, it yielded 59·28 per cent. of ash, which contained silica and alumina in relatively small amounts, oxide of iron in large amounts, and a considerable quantity of phosphoric acid.

To determine if there was free alum in the water, a sample of the clear water, filtered off from the precipitate produced by the alum, was made slightly alkaline with ammonia, and warmed for some time. Only the

merest traces of an alumina reaction could be obtained, and, in fact, in some cases, it was doubtful if a reaction was observable. To prove that no more matter could be precipitated by the addition of a greater amount of alum, samples of the clear filtered water were treated with more alum, but there was in no case any indication of further precipitation on standing.

We consider it, then, established that, by the addition of two grains of alum to the gallon, or half an ounce to one hundred gallons, water can be clarified by standing, and that neither taste nor physiological properties will be imparted to it by this treatment. By increasing the amount of alum, the time required for the separation and settling can be diminished, and *vice versa*, by diminishing the amount of alum added, a greater time will be required for the clarification.

This method is particularly adapted to the clarification of large volumes of water, where filtration is not practical. The cleared water can be racked off to as low a level as possible, after which the sediment should be washed out and the receptacle cleansed by a free use of water.

II. THE EFFECT OF ALUM IN CLARIFYING WATER BY FILTRATION.

In order to test the clarification of water by filtration after addition of alum, the New Brunswick city water was again made the subject of our experiments. It was found that the suspended clayey matters were so fine that the best varieties of filtering papers were unable to remove them. Even when several layers of heavy Schleicher and Schüll paper were used, a very large portion of the suspended matters passed through. This, however, is not surprising, since it is well known that the mineral matters suspended in water are of a remarkable degree of fineness. Thus the water of the river Rhine, near Bonn, cannot be clarified by simple filtration, and takes four months to settle. The addition of certain chemicals aids the filtration of suspended matters in some cases, but it does not always entirely remove them. Calcium chloride and other salts are recommended as effective agents in aiding the removal of suspended matters, but in the case of New Brunswick water, at least, they have no apparent action. The following substances were found to have no effect in aiding the filtration of the water: sodium salts—chloride, carbonate, nitrate, acid carbonate, hydrogen phosphate, acid sulphite, ammonium phosphate, sulphate, biphosphate, tungstate, acetate; potassium salts—hydroxide, chloride, bromide, iodide, acetate, phosphate; ammonium salts—chloride, sulphate, nitrate, acetate; calcium salts—oxide, chloride, sulphate, nitrate. Zinc sulphate and ferrous sulphate (copperas) had no action. Acid sulphate of potassium and of sodium had a slight clearing action. Acetate and chloride of zinc had an apparent action. Ferric chloride (perchloride of iron) clear-

ed perfectly, as also did the nitrate and sulphate of aluminium.

By the addition of a small amount of alum to water, it can be filtered through ordinary paper without difficulty, and yields a brilliantly clear filtrate, in which there is no trace of suspended matter. In our experiments, a solution of alum was added to the water, the whole well mixed by stirring or shaking, and then filtered after standing from one to fifteen minutes. So far as we are able to determine, the coagulative and precipitative action of the alum is immediate upon thorough mixture, and hence it is not necessary to allow the mixture to stand before filtration, but it can be filtered immediately after mixing.

To determine the amount of alum necessary to precipitate this water, alum was added in decreasing amounts to samples of water, which were then filtered through Schleicher and Schüll paper. In this way we found that the minimum limit was about 0.02 gramme of alum to one litre (1.16 grains to one gallon). Beyond that point the action of the alum began to be doubtful, and the water, although clarified by filtration, was not wholly clear. To be sure of complete clarification, we took double this amount—0.04 gramme to one litre (2.3 grains to one gallon)—as a standard calculated to give certain results. This amount can be doubled or trebled without fear of any harmful results, but there is no use of adding any more alum than is sufficient to do the work. The determination of the amount of solids removed from the water by the clarification with alum had not yet been finished.

We consider it, then, as established that, by the addition of two grains of alum to the gallon of water, or half an ounce to the hundred gallons, water can be rendered capable of immediate clarification by filtration. The clear water obtained by filtration, after adding this amount of alum, contains no appreciable amount of free alum, and, in fact, in the majority of cases, ordinary tests fail to reveal its presence.

While the clarification of water by standing is very successful and well adapted to the treatment of large volumes of water, especially when time is not an element of importance, the case will very frequently occur that a relatively small amount of water is to be purified in a short time. In such a case not clarification alone is demanded, but it is necessary that the operation should take as short a time as possible. Again, in order to make this method of clarification practical for domestic use, the operation of filtration must be made extremely simple. No complicated or expensive apparatus should be used, but the filter must be made out of the simplest articles, such as can be found in every household. In this field there is an opportunity for the exercise of considerable mechanical ingenuity, and when the principles of the filtration are understood, and more is known about the different kinds of filtering materials, there will doubtless be many forms of house-filters devised

out of the odds and ends which may be at hand.

It is not a difficult matter to get up a large filter that shall clarify many hundred gallons of water a day in an effective manner. Such apparatus already exists, and is used in manufacturing establishments. In their construction, many points, such, for instance, as the cleansing of the filtering material, have been brought to a high grade of perfection. The difficulty lies in devising some form of simple and cheap filter which will filter a small amount of water as effectively as a relatively large amount, which will be always ready, will always work, will be so simple that any one can understand its operation, can be easily made, not easily broken, but easily repaired if broken, and which will not entail much extra work in order to get a clarified water. The filtering material must be cheap, easily obtainable, easily prepared, capable of being cleansed when clogged by use, or so cheap that it can be thrown away and replaced by new without appreciable expense.

It is evident that the shape, size and arrangement of the filtering apparatus will depend very largely on the kind of filtering material used. Hence we began by experimenting on filtering media. The glass funnel and carefully-folded paper will be of but little service outside of the laboratory. But in cases of great importance, such as the preparation of water for the sick, this method is worthy of attention.

In the large Hyatt filters a mixture of coarsely-ground coke and sand is used, and does most admirable and effective work. Granulated bone charcoal also makes a most excellent filtering bed. The most practical material for domestic use, however, so far as we have been able to ascertain, is cotton. Cotton batting can be bought in the shops for about ten cents a pound, and a pound of it will go a long way in filtering. It makes a coherent filtering layer, and when clogged by use can be cleansed by boiling up in water and rinsing, or, as it is so cheap, can perhaps as well be thrown away and replaced by new.

The simplest form of filter for filtering considerable amounts of water is a tube, one end of which is stuffed with cotton. A drain pipe is the best material, since it can be so easily cleansed. The plug of cotton should be from two to three inches thick, and may be held in place by a round piece of wood fitting into the bottom of the drain pipe at its shoulder, and secured by any suitable means. The piece of wood should be perforated, to allow the water to pass through. The shoulder of the pipe may be set in a circular channel cut in a piece of board, and by means of a central channel the water may be made to run off at a point of delivery. In our next report we shall present plans of simple filters, and the results of our experiments with them.

The most practical form of filter for household use, and one that will easily filter a pitcherful of water in a short space of time, can be made out of a

bottle. The best form is the long kind in which sweet oil is sold, although almost any kind of glass or earthenware bottle will answer. The bottom of the bottle is cracked off, and the sharp edge removed by rasping with a file. The cracking can be done by tying a thin, soft string, soaked in turpentine, around the place where it is intended to crack, leaving as small a knot as possible, then setting fire to the turpentine, holding the bottle bottom up. After allowing the oil to burn for an instant, the end of the bottle is placed quickly in cold water, when, if the operation has been rightly conducted, an even crack will be produced, and the bottom of the bottle will come off easily.

A layer of cotton is now placed in the bottle. The cotton must be worked in water, preferably warm water, in order to remove the adhering air, and to wet it well. A wad of the wet cotton is propped into the bottle and covers the mouth of the neck. Other pieces are dropped in, care being taken to build the layer up evenly, and to add the cotton in rather small pieces. After dropping them in, they should be pressed down and arranged by means of a rod. In this way a layer is made which should be from two to three inches thick. It should not be pressed down too tightly, else it may filter too slowly; neither should it be too light, or water may form channels through it. After a little use the plug generally adapts itself. Particular care should be taken to be sure that the cotton is snug against both sides, since the water is liable to escape there. The plugs, however, are easy to make, and a few attempts will soon teach one all the necessary manipulations.

This bottle filter can be suspended or supported in any convenient way. Perhaps the simplest support is a block of wood having an auger hole bored through the centre, and the edges of the hole reamed out. In this hole the bottle sits securely, and the bevel of the hole catches the shoulder of the bottle, thus holding it upright. To use this filter, it is only necessary to pour the water, which has been previously mixed with the right amount of alum, into it, when the clear water will run in a considerable stream from the bottom, and can be caught in any convenient receptacle. It is well to throw away the first tumblerful that runs through, if the plug is a new one, as a little sediment will pass through at first, but this soon stops. It is also advisable to keep the bottle nearly full while filtering, as this hastens filtration.

The mixing of the water with the alum previous to the filtration should be done in a separate receptacle. The only requisite here is that the vessel in which the mixing is done must be clean. A pail, jug, can, or any other vessel used in the kitchen will do. It is well to have the pail or can marked on the inside with scratches so as to be able without difficulty to judge how much water there is in it, since the amount of alum should be added in

about the right proportions. The eye gets very accurate in judging the volume after a little practice, but it is better and just as easy to be accurate. A clean tin can of two to four gallons capacity is a good size, and, if possible, should not be used for any other purpose than for the drinking water. It should be kept scrupulously clean, and after each use should be washed out and dried. It can be graduated by pouring into it a gallon of water, and marking with a file or other sharp point a scratch just at the level of the water. Then another gallon is poured in, and its level also marked. In this way a graduation is easily made which is sufficiently accurate for all the purposes here intended. As a rule, a can of four gallons capacity will be found quite large enough to filter the water used by a family of average size. The necessary amount of the alum solution is added to the water, the whole well mixed by stirring, and then poured into the filter. Here, again, one or two points should be observed. The mixing is best done with a long-handled spoon. A very practical stirrer is a small cake turner, for by means of its flat end a most thorough mixing can be effected. This mixer should not be used for any other purpose than to mix the water. Experience shows that, if the vessels used for mixing or holding the water are not kept perfectly clean, the water may acquire a taste, and this will be laid to the process instead of to lack of care. To facilitate the pouring into the filter, it is well to have the can provided with a mouth or spout. In fact, there is no form of can better than the regular garden watering-pot, with its long spout.

The solution of alum is made as follows: Dissolve ~~half~~ an ounce of alum in a cup of boiling water, and when it is all dissolved, pour into a quart measure and fill to a quart with cold water. (This solution should be kept in a bottle labelled "ALUM.") Fifty-four drops of this solution contain 2.3 grains of alum, which is the amount to be added to one gallon of water. The old-fashioned teaspoon holds about forty drops; the new spoons, however, hold about seventy drops. Hence, a modern teaspoon, scant full, will be about the right amount to add to every gallon of water to be filtered. No harm would be done if by mistake two teaspoonfuls are added; in fact, ten teaspoonfuls would have to be added to bring the amount of alum up to the figure recommended by Jeunet (*loc. cit.*). A more satisfactory method will be to procure a small measuring glass. One fluid drachm will be the right amount. It will be found, without doubt, that the amount required for some waters will be even less than that suggested above. We would suggest, therefore, that those who use this method of clarification determine for themselves by experiment how little of the solution is required to make the water they use run through the filter perfectly bright and clear.—*Chemical Laboratory of Rutgers College.*